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G1N

(54) Measuring the rate of gas flow in a duct

(57) At the place of measurement in the duct is a throttling flange (5), or a venturi nozzle, and a separate measuring duct (9, 10, 13) is connected through outlets arranged upstream and downstream of the throttling flange to divert a partial gas flow through the measuring duct. A temperature sensitive, flow sensing resistor (14) is attached to a measuring cell (13) in the measuring duct and heated electrically, preferably at a constant current. The voltage drop across this resistor (14) constitute the electrical measuring output signal. Throttling arrangements (11, 12) in the measuring duct ensure a laminar flow through the measuring cell (13). A temperature compensating resistor can be provided.

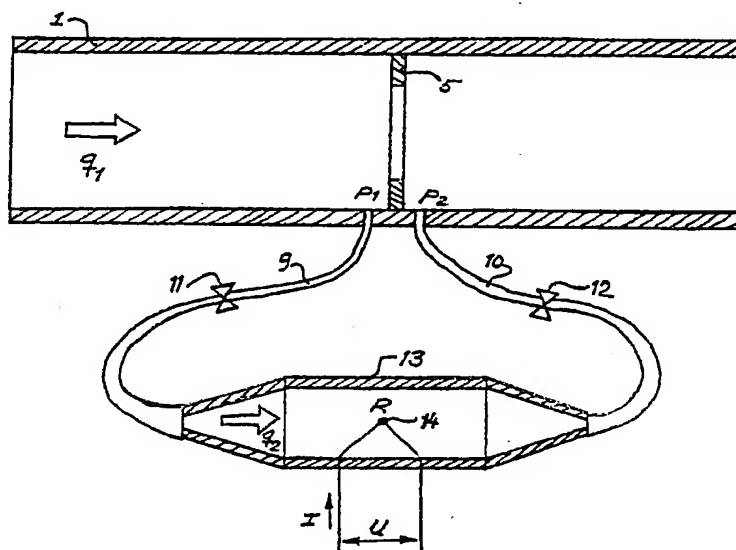


Fig. 3

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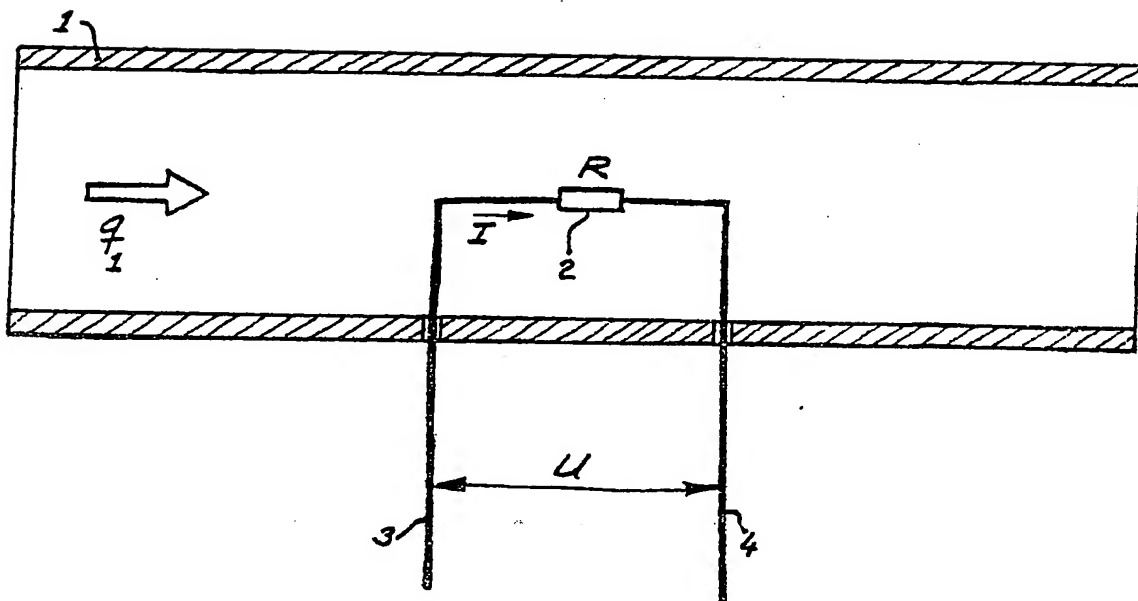


Fig. 1

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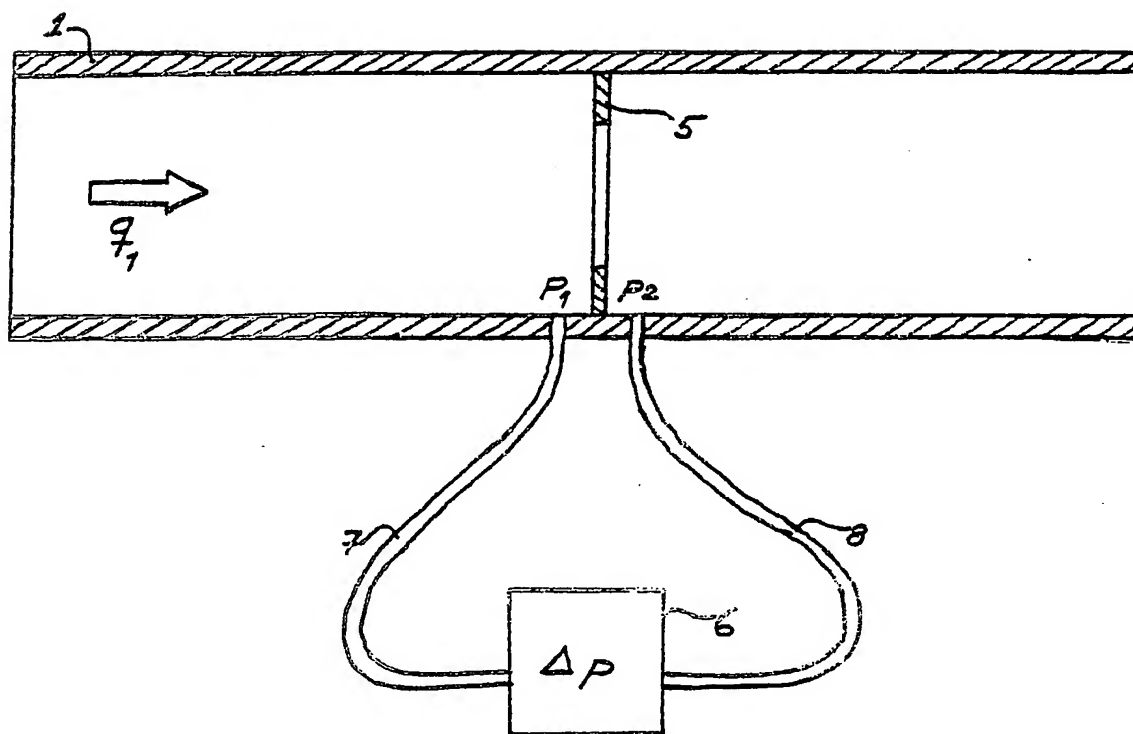


Fig. 2

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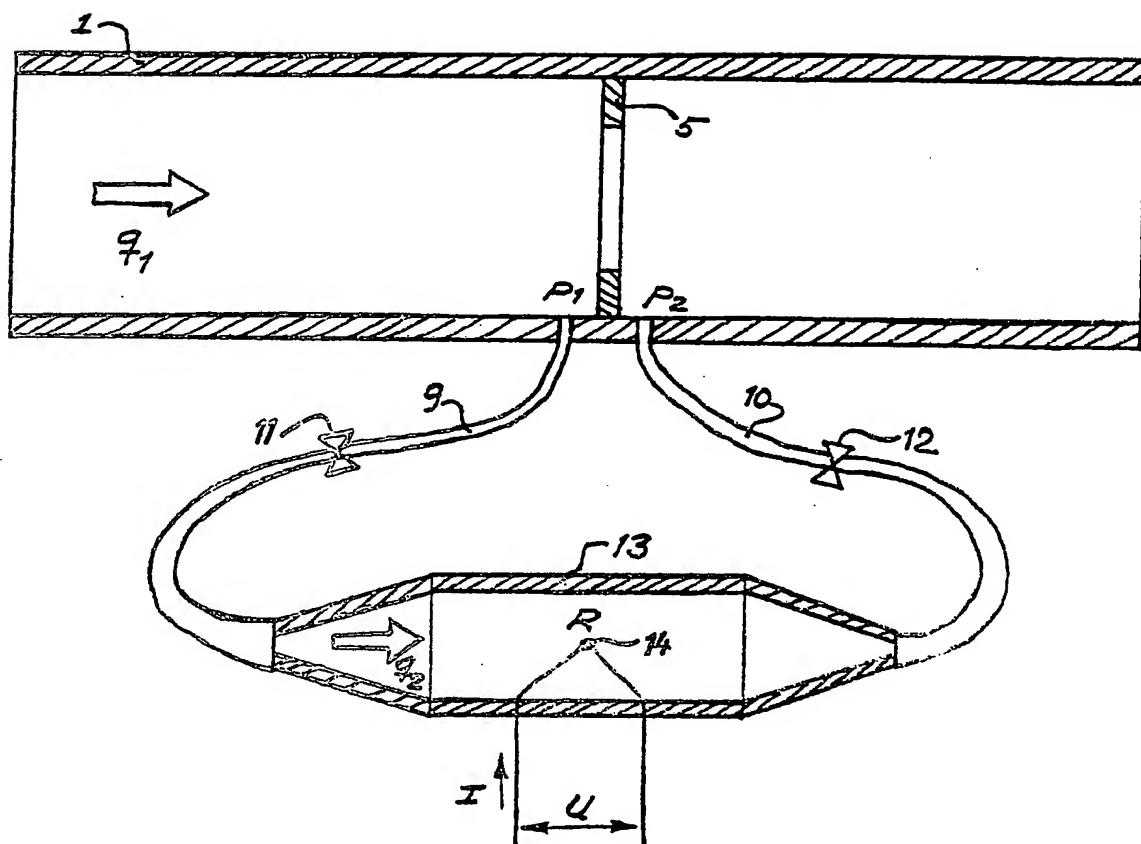
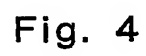


Fig. 3



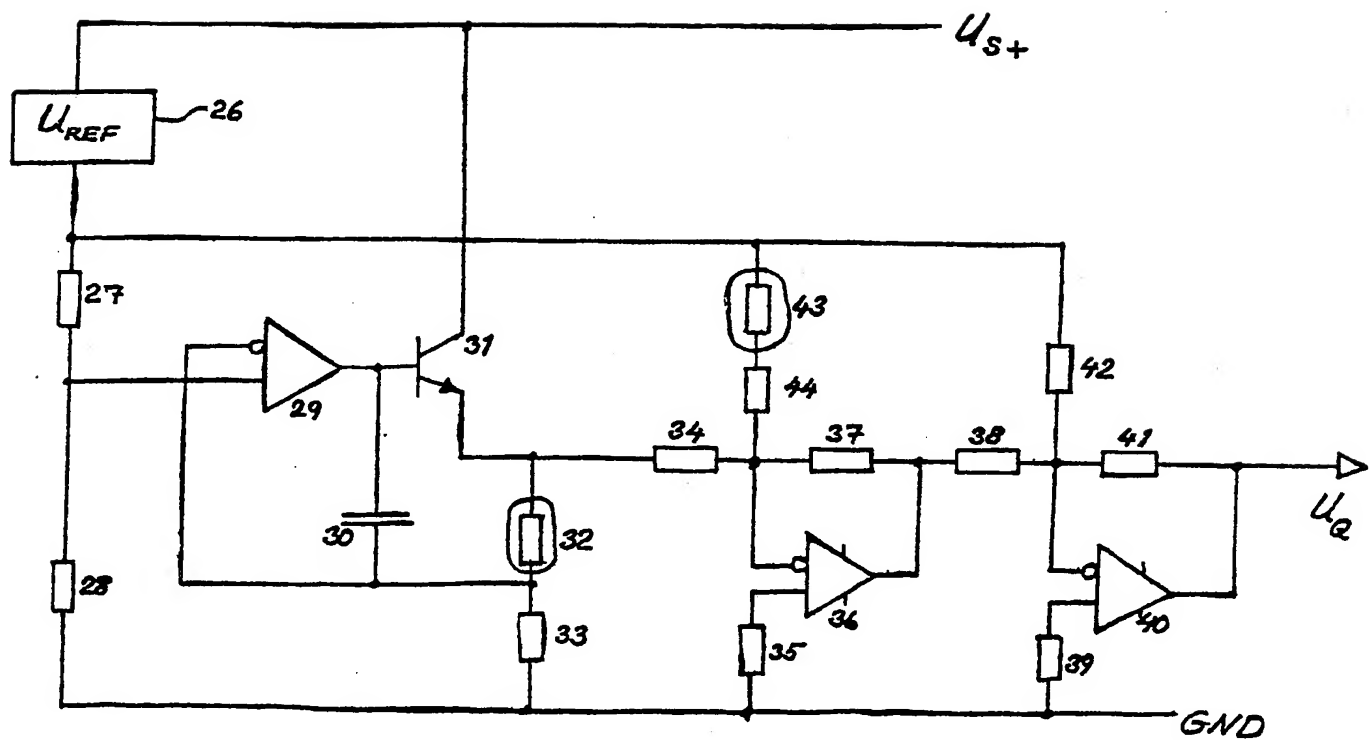


Fig. 5

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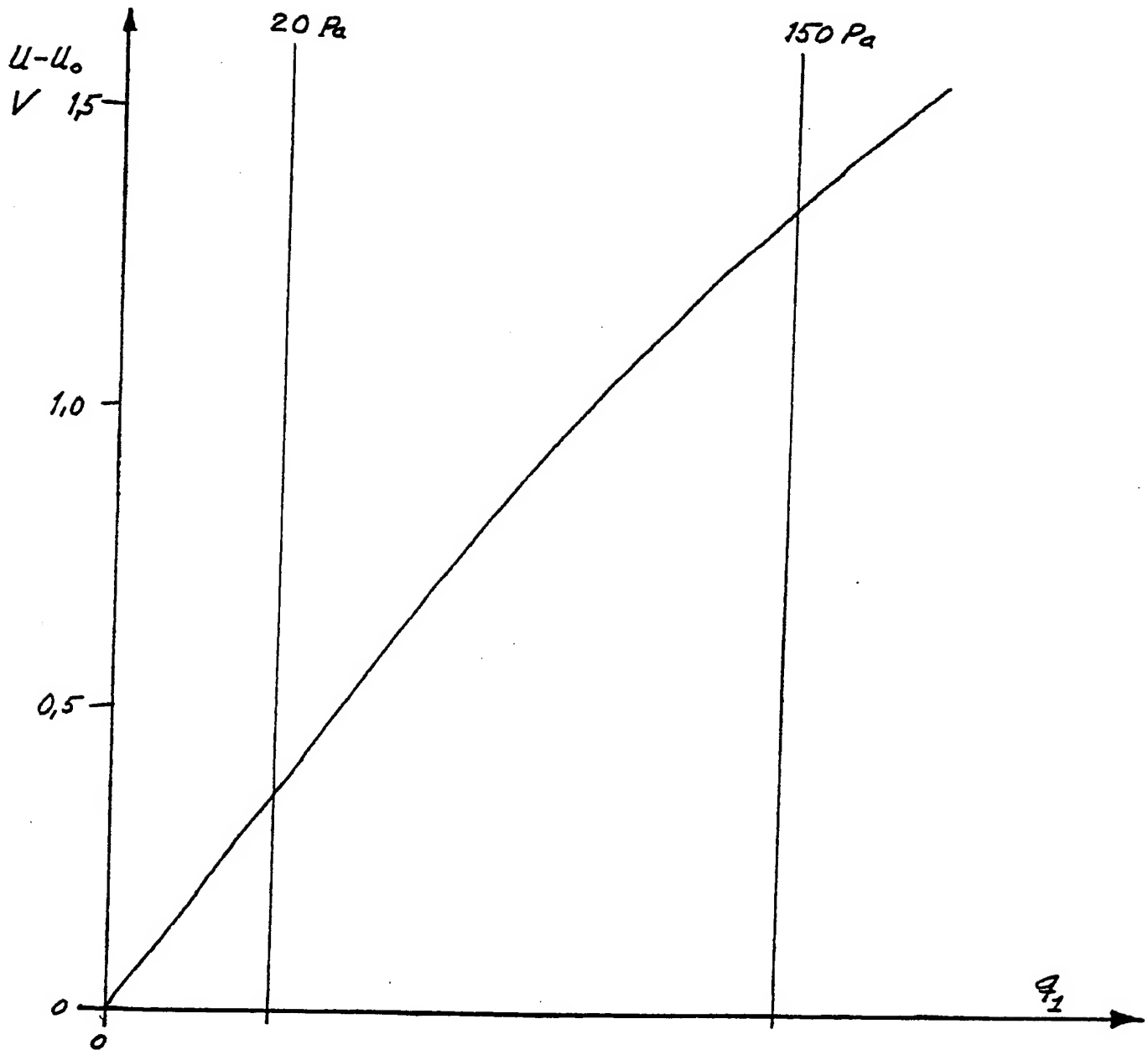


Fig. 6

SPECIFICATION

A method for measuring the rate of gas flow in a duct and design of a gas flow-meter for performance of that method

5 The present invention relates to a method for measuring the rate of gas flow in a duct. The invention also includes the design of a gas flowmeter for performance of the method. 5

Measuring methods known for determining the rate of gas flow in a pipe by means of an electrical measuring output signal from a measuring body result in a marked nonlinear relation between the rate of flow and the measuring signal. In actual operation, this nonlinearity must be adjusted in special electronic 10 circuits before a practically applicable control signal is obtained, a procedure which not only requires unnecessarily complex equipment, but also increases the risk of erroneous measurements. 10

It is an object invention is to seek a simple and reliable method for flow controllers to measure flow rates in ventilation systems, but also to utilize it more generally in all kinds of connections, where the rate of gas flow 15 has to be measured. According to the invention there is provided a method of measuring the rate of gas flow in a duct, in which a throttling flange, a venturi nozzle or a similar device is arranged for measuring purposes and to which a measuring duct is connected through pipes and pressure outlets are located upstream and downstream of the throttling flange to divert a partial gas flow through the measuring duct, wherein said 20 partial gas flow is limited through one or several throttling arrangements located in the measuring duct in such a way that it thereby is given a laminar flow which is proportional to the pressure drop across the throttling flange, is bypassed one measuring cell placed in the measuring duct and provided with a temperature sensitive, flow sensing resistor which is electrically heated, and an electrical measuring output signal is emitted from the measuring cell. 20

Thus, this invention provides a measuring method and a device electrically producing, at the measuring body, a measuring signal which is approximately linearly proportional to the rate of gas flow searched for in a pipe. 25

A method embodying the invention is hereinafter described by way of example with reference to the accompanying drawings.

30 Brief description of drawings

Figure 1 shows the principle of flow measurement according to known technology by means of an electrically heated instrument, e.g., a hot-wire anemometer, located in a ventilation duct or some other pipe through which gas passes; 30

Figure 2 shows the principle of flow measurement according to known technology by means of a throttling flange and a differential pressure gauge, 35

Figure 3 shows the principle of flow measurement by means of the invention; 35

Figure 4 shows in detail the design of a gas flowmeter in accordance with the invention;

Figure 5 shows the design of a measurement and control circuit of a gas flowmeter in accordance with the invention; and

Figure 6 is a diagram which shows current variations across a flow sensing resistor as the function of the measured gas flow in a measuring probe used in a measuring system according to the invention. 40

One of the most commonly used methods to determine a gas flow electrically is to measure, in one way or the other, the cooling effect on an electrically heated body placed in a gas flow. The principle of this measuring method is illustrated by Figure 1, where R symbolises the resistance of the current passing 45 through an electrically heated probe 2, I the current through the probe and U the differences in current between the supply lines 3 and 4. To give a clearer picture of the method, the description contains a number of constants - k_1, k_2, \dots, k_{10} - but whose exact expression is irrelevant for the further line of reasoning. To ensure that the device functions as a flowmeter, resistance R must change according to the temperature, but completely irrespective of the characteristics of the probe, the developed effect P is in general equal to: 45

$$50 \quad P = U \cdot I = R \cdot I^2 \quad (1) \quad 50$$

At equilibrium the same heat effect of the gas flow q_1 in the duct is removed according to the formula:

$$55 \quad P = (k_1 + k_2 \sqrt{q_1}) \Delta t \quad (2) \quad 55$$

where Δt represents the temperature difference between the probe and the gas. If temperature of the probe, gas temperature and effect are known, the gas flow can thus be calculated as:

$$60 \quad q_1 = \left(k_3 \cdot \frac{P}{\Delta t} - k_1 \right)^2 \quad (3) \quad 60$$

As measuring principle the choice is made, as a rule, to vary the current in such a way that the temperature of the probe is kept constant with the result that the resistance R also is constant. In this case, equation 3 can be written as:

$$q_1 = k_3 \cdot \left(\frac{R \cdot I^2}{\Delta t} - k_1 \right)^2 \quad (4)$$

which, if the gas temperature is constant, can be simplified to:

$$q_1 = k_4 \cdot (I^2 - I_0^2)^2 \quad (5)$$

where the constant I_0 is equal to the current at the gas flow $q_1 = 0$. The advantage of this measuring method is that it is not necessary to know the exact temperature dependence of the resistance. For the same reason, other closely related measuring methods are usually discarded, which could be based on the possibility, e.g. to keep the current or the voltage constant. On the other hand, an obvious disadvantage is the very marked nonlinearity which is expressed by equation 5.

Figure 2 shows another known measuring method which, e.g., often is used for manual precision measurements in ventilation ducts. The pressure drop across the throttling flange 5 as measured by the pressure gauge 6 is in this case quadrilaterally dependent of the flow:

$$\Delta p = p_1 - p_2 = k_5 \cdot q_1^2 \quad (6)$$

which also can be expressed as

$$q_1 = k_6 \cdot \sqrt{\Delta p} \quad (7)$$

The connection between gas flow and measured value is also in this case considerably nonlinear, and in view of the low pressure drops permissible in a ventilation duct, the pressure gauge must be highly sensitive. An obvious advantage, however, is the fact that the measured value is a direct measurement of the average gas flow q_1 which is not certain in the case of the electrically heated probe according to Figure 1, where instead the measured value is the measurement of the local velocity exactly in the measuring point.

Figure 3 shows the principle of the invention. To give a clear illustration, measuring cell 13 is shown to an enlarged scale. In a typical design its diameter can be of the size 3-10 mm, whereas the diameter of a main duct 1, e.g., in a ventilation system can measure 0.1-1 m. The pressure drop across measuring flange 5 forces a small gas flow q_2 through the measuring cell, and its supply pipes 9 and 10 are provided with one or several throttling arrangements. One throttling arrangement is enough to ensure the function of the device, but with two throttling arrangements, 11 and 12, respectively, a gas volume is trapped in the measuring cell and moderates interruptions of short duration.

A sufficiently forceful throttling arrangement produces the gas flow q_2 directly proportional to the pressure drop:

$$q_2 = k_7 \cdot \Delta p \quad (8)$$

Combined with equation 7

$$q_1 = k_8 \cdot \sqrt{q_2} \quad (9)$$

is consequently obtained.

In addition, for an electrically heated probe 14 inserted in the measuring cell equations 1 and 3 give:

$$q_2 = k_3 \cdot \left(\frac{U \cdot I}{\Delta t} - k_1 \right)^2 \quad (10)$$

which included in equation 9 results in:

$$q_1 = k_9 \cdot \left(U \cdot \frac{I}{\Delta t} - k_1 \right) \quad (11)$$

If current U may represent the measuring output signal from the probe, and the quotient $I/\Delta t$ is kept constant, a completely linear relation can be obtained from equation 11:

$$q_1 = k_{10} (U - U_0) \quad (12)$$

where U_0 corresponds to the current over the measuring probe at the gas flow $q_1 = 0$.

If minor deviations from the perfect linearity can be accepted, which often is the case in connection with control operations, an especially simple and reliable performance of the invention can be obtained by keeping the current I constant through the electrically heated probe. This requires that the temperature difference Δt is not allowed to vary too much, which can be implemented by making the probe 14 as an amply heated semiconductor element with a great negative temperature coefficient. When the probe is cooled by the gas flow q_2 , the insignificant temperature decrease already at this stage results in a sharp rise in the resistance R of the probe which, by the constant current I , also gives a considerable increase in the measuring voltage U . This latter effect brings about an increased heat generation in the probe which contributes to maintaining the temperature of the probe.

Figure 6 shows a diagram of a typical example of measurement by means of a device according to Figure 3. The probe 14 consists in this case of a roughly 0.4 mm large thermistor which is heated to approximately 150°C by a current of 10.0 mA. As appears, the obtained measuring output signal is of an unusually large magnitude and the curve deviates only slightly from a straight line within the pressure drop ranges 20 - 150 Pa which corresponds to the normally applicable range of a ventilation system.

Figure 4 shows a special design of the device in Figure 3. The entire measuring cell 15 can be made in one piece, e.g., by one die-cast operation, which makes it possible for the throttling arrangements 18 and 19 in the supply pipes to be integrated in the measuring cell in the form of capillary tubes. The pressure connection is made to the openings 16 and 17, and the cavities 20 and 21 counteract quick pressure fluctuations. The electrically heated probe 23 is attached to the measuring duct 22 through the electrical connections 25. A temperature sensing unit 24, e.g., in the form of an unheated thermistor, allows compensation for changes in temperature of the gas.

Figure 5 shows the principle of how the invention in a very simple way may be electronically implemented. As the custom is, such trivial items as supply of current to the operation amplifiers 29, 36 and 40 are not shown. The current through the electrically heated probe 32 is kept constant by the operation amplifier 29 which controls the voltage drop across the resistor 33 to remain equal to the reference voltage from the voltage stabilizer 26 as obtained across the voltage separator 27-28. The sum of the voltage drop across the units 32 and 33 is amplified and inverted by the amplifier 34-35-36-37. The end amplifier 38-39-40-41-42 adds constant voltage to the inverted signal from the unit 36 which corresponds to a subtraction of the constant voltage drop across the resistor 33 and of the voltage constant U_0 in equation 12. The reinverted output signal U_Q thus can be made direct proportional to the measured gas flow q_1 , by analogy with the curve in Figure 6. The resistor 43 corresponds to the temperature sensor 24 shown in Figure 4, by way of which variations in the gas temperature can be compensated.

Including temperature compensation in other parts of the circuit, counter-balancing of the weak bend of the measuring value characteristic by means of nonlinear resistance, performance of parts of the signal treatment in a microprocessor and other similar variations are in this context considered trivial and within the scope of the invention.

CLAIMS

1. A method of measuring the rate of gas flow in a duct, in which a throttling flange, a venturi nozzle or a similar device is arranged for measuring purposes and to which a measuring duct is connected through pipes and pressure outlets are located upstream and downstream of the throttling flange to divert a partial gas flow through the measuring duct, wherein said partial gas flow is limited through one or several throttling arrangements located in the measuring duct in such a way that it thereby is given a laminar flow which is proportional to the pressure drop across the throttling flange, is bypassed one measuring cell placed in the measuring duct and provided with a temperature sensitive, flow sensing resistor which is electrically heated, and an electrical measuring output signal is emitted from the measuring cell.
2. A method of measuring the rate of gas flow according to Claim 1, in which the voltage drop (U) across the flow sensing resistor constitutes the electrical measuring output signal, and in which this measuring output signal is brought into a linear relation to the gas flow (q_1) searched for in the main duct by keeping the current (I) through the flow sensing resistor in a linear relation to the temperature difference between said resistor and the ambient gas.
3. A method of measuring the rate of gas flow according to Claim 1, in which the voltage drop (U) across the flow sensing resistor constitutes the electrical measuring output signal, in which measuring output signal is brought into an approximately linear relation to the gas flow (q_1) searched for in the main duct by keeping the current (I) through the flow sensing resistor constant, in which the resistor which shows a high negative temperature coefficient is brought to a high temperature, and in which compensation of changes in the gas temperature takes place by comparisons of the measured value from the active, flow sensing resistor

with the measured value from a similar, passive resistor arranged in a stationary gas volume at the same pressure and temperature.

4. A method of measuring the rate of gas flow according to Claim 1, in which the voltage drop (U) across the flow sensing resistor constitutes the electrical measuring output signal, in which the measuring output signal is brought into an approximately linear relation to the gas flow (q_1) searched for in the main duct by keeping the current (I) through the flow sensing resistor constant, in which the resistor which shows a high negative temperature coefficient is brought to a high temperature and in which compensation of changes in the gas temperature takes place through correction of the measured value from the flow sensing resistor by a temperature gauge arranged at said resistor.

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5. A method of measuring the rate of gas flow according to Claim 3 or Claim 4, in which the resistor is brought to a temperature of about 150°C.

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6. A gas flowmeter for performance of the method according to Claims 1-5, in which supply pipes of the measuring duct, throttling arrangements and measuring cell are made up of an integrated duct system in one block of arbitrarily selected material, said throttling arrangements being capillary tubes, cavities moderating interruptions being located between the throttling arrangements and the measuring cell, the measuring cell contains an electrically heated, flow measuring sensor which is electrically connected through isolated connections and in which a temperature measuring device, for instance in the form of a temperature sensitive resistor, is placed in the duct system for temperature compensation.

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7. A gas flowmeter for performance of the method according to Claims 1-5, in which supply pipes of the measuring duct, throttling arrangements and measuring cell are made up of an integrated duct system in one block of arbitrarily selected material, said throttling arrangements being capillary tubes, cavities moderating interruption are located between the throttling arrangements and the measuring cell, the measuring cell containing an electrically heated, flow measuring sensor which is electrically connected through isolated connections in which a reference transducer identical to the said sensor is located in a closed reference duct similar to the measuring duct for temperature compensation, and in which said reference duct and measuring duct communicate with each other in such a way that the same gas pressure is obtained at the reference transducer as at the flow measuring sensor.

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8. A gas flowmeter according to Claim 6 or Claim 7, in which the block with the integrated duct system displays a form which is suitable for manufacture by compression moulding, pressing of powder or similar techniques.

9. A gas flowmeter according to any of Claims 6 to 8, in which an electronic measuring and control circuit which is arranged for treatment of the measuring output signal displays a current controller which is provided to supply constant current to the heated, flow sensing resistor, in which an inverting amplifier is arranged to amplify the measuring output signal from said resistor and to add a temperature correcting output signal over a circuit containing a temperature measuring resistor, and in which an inverting end amplifier is arranged to subtract the constant components from the temperature corrected measuring output signal.

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10. A method of measuring the rate of gas flow in a duct, substantially as hereinbefore described with reference to Figures 3 to 6 of the accompanying drawings.

11. A flowmeter for carrying out the method of any one of Claims 1 to 5 or 10, substantially as hereinbefore described with reference to Figures 3, 4 or 5 of the accompanying drawings.

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